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Regional patterns of growth and instability of apple production in Himachal Pradesh

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Abstract
The study analyzes the growth performance and instability of apple cultivation in major districts of Himachal Pradesh over 15 years (2009-10 to 2023-24). Secondary data were collected from the Directorate of Economics and Statistics and the National Horticulture Board. The Compound Annual Growth Rate (CAGR), Coefficient of Variation (CV) and Cuddy-Della Valle Instability Index (CDVI) were employed to examine trends in area, production and productivity. Results revealed that while the overall area under apple cultivation has expanded across the state, the rate of growth has been uneven among districts. Shimla, Kinnaur and Kullu recorded relatively higher productivity and stability, whereas Mandi, Sirmour and Kangra exhibited lower and more unstable production. The analysis indicated that production instability may be caused by yield fluctuations due to climatic variability, irregular rainfall, pest attacks and ageing orchards. The CDVI values confirmed that productivity variation contributed more to instability than area changes. The study recommends adopting resilient varieties, improving irrigation and strengthening post-harvest infrastructure to achieve sustainable and stable apple production.

Keywords: Apple, Himachal Pradesh, Growth rate, Instability analysis

Introduction
Himachal Pradesh is known as the “Fruit Bowl” of India (Srivastava and Dogra, 1991) [5]. Its moderate climate and lush valleys make it an ideal region for apple cultivation, referring to it as “Apple State”. Himachal is known for the production of quality apples (Firdous and Manoj, 2018) [3]. Apple production in Himachal Pradesh is primarily concentrated in the districts of Kullu, Shimla, Kinnaur, Mandi, Chamba, parts of Sirmour and the Lahaul and Spiti region. Apple orchards expanded from merely 400 hectares in 1950 to over 115,680 hectares by 2023, demonstrating massive sector growth (World Bank Group, 2024). In 2023-24, the total area under fruit crops in the state was 2,37,368 hectares, of which 1,16,338 hectares were dedicated to apple cultivation. The total fruit production in the state for 2023-24 was 6,37,229 metric tonnes, with apples contributing 5,06,687 metric tonnes (State Horticulture Statistics at a Glance, 2024). Shimla district leads apple production, accounting for 55 per cent of the total output, followed by Kullu district with 20 per cent in 2023-24. Over the last 15 years (2008-09 to 2022-23), the average area dedicated to fruit crops in Himachal Pradesh was 2,24,089 hectares, with apples occupying 1,08,911 hectares. During the same period, average annual fruit production was 6,81,654 metric tonnes, of which apples contributed 5,51,648 metric tonnes (State Horticulture Statistics at a Glance, 2024). Apples constitute 48.6 per cent of the total fruit-growing area and 80 per cent of the total fruit production in Himachal Pradesh, underscoring their critical role in the state's economy with an estimated economy of nearly ₹4000 crore (Himachal Apple). Apples from Himachal Pradesh are sold both domestically and internationally. However, despite expansion in area and production, apple growth in Himachal Pradesh has fluctuated due to climatic variability, changing orchard management practices and infrastructure challenges, highlighting the need to study growth trends and instability for sustainable planning. This study focuses on the growth trends of apple cultivation in Himachal Pradesh, examining changes in area, production and productivity across major districts to assess performance and stability over time.

Material and methods

For this study, the secondary data were collected from the Directorate of Economics and Statistics and the National Horticulture Board for a period of 15 years, spanning from 2009-2010 to 2023-24. It analyzed the growth rate and instability of apple production across the major apple-producing districts of Himachal Pradesh, namely Shimla, Kullu, Mandi, Chamba, Kinnaur, Sirmour, Lahaul and Spiti, Kangra and Solan. The statistical tools such as Compound annual growth rate (CAGR), coefficient of variation and instability index were employed to assess the variability of apple production in these regions.

Compound annual growth rate (CAGR)

To estimate the compound annual growth rates (CAGR) of area, production and productivity of apple, an exponential form of regression analysis was employed. The regression equation in the following form was applied.

$$Y_t = a\, b^t\, U_t \quad (1)$$

Where,
Y = Dependent variable (area or production or productivity) in the year 't'
a = Intercept indicating Y in the base period (t=0)
b = Regression coefficient
t = Time period
U^t = error term

The equation (1) was transformed into log linear form and written as;

$$\text{Log } Y = \log a + t \log b + U_t \quad (2)$$

The coefficients were estimated by using the Ordinary Least Squares (OLS) technique.
Compound growth rate (g) was then computed

$$g = (b - 1) \times 100 \quad (3)$$

Where,
g = Compound growth rate in per cent per annum
b = Antilog of log b
The standard error of the growth rate was estimated and tested for its significance with 't' test statistic.

Instability index

To assess the instability of growth in the area, production and productivity of apple, the coefficient of variation and Cuddy Della Valle Index were employed. Although the Coefficient of Variation (CV) is a widely used measure of instability, it tends to overestimate variability in time series data that exhibit long-term trends. The CDVI, on the other hand, adjusts for these trends and provides a more reliable measure of actual instability.

$$\mathbf{CV} = \frac{\textbf{Standard deviation } (\boldsymbol{\sigma})}{\textbf{Mean } (\bar{\mathbf{X}})} \times \mathbf{100}$$

$$\boldsymbol{CDVI} = \boldsymbol{CV}\sqrt{\mathbf{1} - \boldsymbol{Adj\ R^2}}$$

Where,
CV = Coefficient of variation (in percent)
Adj R^2 = Coefficient of determination from a time trend regression adjusted by the number of degrees of freedom

Ranges of CDVI-

- Low instability- 0-15
- Medium instability-15-30
- High instability-30 and above

Results

Growth in area, production and productivity of apples

The trends in apple cultivation across major apple-producing districts of Himachal Pradesh from 2009-10 to 2023-24 reveal a mixed pattern of growth in area, production and productivity.

Table 1: Area of apple in major districts of Himachal Pradesh (2009-10 to 2023-24) (Hectare)

Year	Shimla	Kullu	Mandi	Chamba	Kinnaur	Sirmour	Lahaul and Spiti	Kangra	Solan
2009-10	33579	23870	15531	11990	9838	3248	959	450	95
2010-11	34612	24002	15687	12196	9999	3144	1320	431	87
2011-12	35778	24503	15842	12509	10100	2980	1410	430	85
2012-13	37249	25372	16018	12766	10116	2948	1473	420	71
2013-14	37542	25624	16077	12997	10487	2912	1579	393	65
2014-15	38781	25813	16311	12818	10953	2753	1653	396	60
2015-16	39728	26029	16434	12554	11164	2592	1673	423	58
2016-17	40160	26633	16568	12510	11219	2566	1682	434	45
2017-18	40566	26794	16638	12594	11179	2579	1702	455	42
2018-19	40961	27053	16748	12539	10973	2500	1746	493	54
2019-20	41765	27209	16849	12407	10891	2574	1762	530	59
2020-21	42085	27258	16930	12405	10911	2580	1776	525	73
2021-22	42292	27256	16933	12436	10926	2601	1793	570	94
2022-23	42315	27390	17009	12603	10926	2737	1797	571	200
2023-24	42544	27423	17121	12692	10930	2745	1825	582	235
CAGR	1.67***	1.04***	0.69***	0.10	0.75***	-1.34***	3.18***	2.60***	4.05
CV (%)	7.26	4.60	3.01	1.88	4.22	0.08	0.14	13.45	60.66
CDVI	2.08	1.43	0.55	1.84	2.80	0.05	0.08	7.21	56.45

The area under apple cultivation in Himachal Pradesh showed an overall increasing trend from 2009-10 to 2023-24, though with notable regional variations as presented in Table 1. Shimla remained the leading district, expanding steadily from 33,579 ha to 42,544 ha with a CAGR of 1.67 per cent, followed by Kullu (1.04%) and Mandi (0.69%). Kinnaur also showed a modest rise (0.75%), while Chamba recorded almost stagnant growth (0.10%). In contrast,

Sirmour registered a decline in area with a negative growth rate of -1.34 per cent. Among emerging regions, Lahaul and Spiti recorded the highest growth rate (3.18%), indicating a gradual shift of apple cultivation towards higher altitudes, while Kangra (2.60%) and Solan (4.05%) showed positive but unstable trends. The variability analysis revealed low instability in traditional districts like Shimla, Kullu and Mandi, suggesting stable expansion, whereas high instability in Solan and Kangra reflected inconsistent area trends. The results indicate that apple cultivation in Himachal Pradesh is expanding slowly in traditional areas, with signs of diversification into new high-altitude regions due to changing climatic conditions, while lower-altitude districts are experiencing stagnation or decline.

Table 2: Production of apple in major districts of Himachal Pradesh (2009-10 to 2023-24) (MT)

Year	Shimla	Kullu	Mandi	Chamba	Kinnaur	Sirmour	Lahaul and Spiti	Kangra	Solan
2009-10	171945	54385	8659	3962	40289	242	193	401	28
2010-11	602684	191212	22315	10789	63781	673	194	425	38
2011-12	168634	44619	4417	3074	53290	457	126	400	19
2012-13	259779	87906	9015	2739	52020	481	169	259	25
2013-14	499422	152654	24229	7189	54044	644	200	322	18
2014-15	407751	104589	24709	26054	59196	2290	277	309	23
2015-16	482388	143475	48608	24018	75202	2821	272	324	14
2016-17	265987	89570	38344	11734	60210	1688	305	277	14
2017-18	251897	78948	42078	18959	52189	1896	300	285	15
2018-19	169962	76019	43968	12688	61673	3670	302	298	17
2019-20	437024	131194	57158	28083	56864	4291	302	304	19
2020-21	247179	92260	49143	14451	73330	4017	310	336	23
2021-22	369720	115049	49792	18240	48678	9377	751	252	26
2022-23	346993	145103	59174	26270	83324	10593	518	333	26
2023-24	281106	102860	47727	9980	58299	5534	705	350	95
CAGR	0.38	2.18	15.47***	11.22***	1.79	27.61***	10.45***	-1.44	2.58
CV (%)	38.76	35.62	50.00	57.77	17.90	0.95	0.55	15.33	72.28
CDVI	38.73	34.52	29.63	45.59	16.11	0.33	0.25	13.93	70.23

The production of apples in Himachal Pradesh showed wide fluctuations from 2009-10 to 2023-24 across districts. Shimla remained the leading producer, though with high variability and a marginal growth rate (CAGR 0.38%), reflecting the influence of climatic factors and uneven bearing. Kullu recorded moderate growth (2.18%), while Mandi (15.47%) and Chamba (11.22%) showed rapid increases in production, indicating the growing importance of these districts. Kinnaur exhibited steady but moderate growth (1.79%), whereas Sirmour (27.61%) and Lahaul & Spiti (10.45%) registered sharp growth from smaller bases, suggesting a gradual expansion of apple cultivation to non-traditional and higher-altitude areas. In contrast, Kangra recorded a slight decline (-1.44%) and Solan showed unstable production trends. Overall, production remained concentrated in Shimla, Kullu and Kinnaur, but high instability in output reflects strong climatic influence and variability in yields across years.

Table 3: Productivity of apple in major districts of Himachal Pradesh (2009-10 to 2023-24) (MT/Hectare)

Year	Shimla	Kullu	Mandi	Chamba	Kinnaur	Sirmour	Lahaul and Spiti	Kangra	Solan
2009-10	5.12	2.28	0.56	0.33	4.10	0.07	0.20	0.89	0.29
2010-11	17.41	7.97	1.42	0.88	6.38	0.21	0.15	0.99	0.44
2011-12	4.71	1.82	0.28	0.25	5.28	0.15	0.09	0.93	0.22
2012-13	6.97	3.46	0.56	0.21	5.14	0.16	0.11	0.62	0.35
2013-14	13.30	5.96	1.51	0.55	5.15	0.22	0.13	0.82	0.28
2014-15	10.51	4.05	1.51	2.03	5.40	0.83	0.17	0.78	0.38
2015-16	12.14	5.51	2.96	1.91	6.74	1.09	0.16	0.77	0.24
2016-17	6.62	3.36	2.31	0.94	5.37	0.66	0.18	0.64	0.31
2017-18	6.21	2.95	2.53	1.51	4.67	0.74	0.18	0.63	0.36
2018-19	4.15	2.81	2.63	1.01	5.62	1.47	0.17	0.60	0.31
2019-20	10.46	4.82	3.39	2.26	5.22	1.67	0.17	0.57	0.32
2020-21	5.87	3.38	2.90	1.16	6.72	1.56	0.17	0.64	0.32
2021-22	8.74	4.22	2.94	1.47	4.46	3.61	0.42	0.44	0.28
2022-23	8.20	5.30	3.48	2.08	7.63	3.87	0.29	0.58	0.13
2023-24	6.61	3.75	2.79	0.79	5.33	2.02	0.39	0.60	0.40
CAGR	-1.27	1.13	14.68***	11.11**	1.04	29.35***	7.04***	-3.94***	-1.41
CV (%)	42.03	37.41	48.52	57.58	16.44	0.95	0.46	21.23	23.84
CDVI	41.62	37.08	29.58	45.64	15.79	0.33	0.31	12.05	23.27

The productivity of apples in Himachal Pradesh showed wide year-to-year fluctuations from 2009-10 to 2023-24. Shimla, the main producing district, recorded a slight decline in productivity (CAGR -1.27%) with high variability, while Kullu showed marginal improvement (1.13%). Mandi (14.68%) and Chamba (11.11%) registered the highest growth rates, reflecting improved yields and management. Kinnaur maintained stable productivity (1.04%) with low variability, indicating consistent performance. Among emerging districts, Sirmour (29.35%) and Lahaul & Spiti (7.04%) showed notable gains, suggesting expansion of apple cultivation into new high-

yielding zones. In contrast, Kangra and Solan recorded negative growth, indicating poor suitability. Overall, productivity trends highlight stagnation in traditional apple areas and rising potential in higher-altitude and non-traditional regions.

Discussion

The results depicted in Table 4.3 indicate that the area under apple orchards during the study period has expanded steadily, reflecting the continued interest and investment in apple farming. Districts like Shimla (CAGR 1.67%), Kullu (1.04%), Lahaul and Spiti (3.18%) and Solan (4.05%) recorded notable increases in area. This upward trend is likely due to favourable market conditions, supportive government policies and a long-standing tradition of apple cultivation in the region. However, increasing area alone is not sufficient to ensure higher producers' income unless it is complemented by growth in production and productivity.

In terms of production, the performance varies widely. While districts such as Mandi (15.47%), Sirmour (27.61%) and Chamba (11.22%) saw strong growth, Shimla, despite its status as a traditional apple hub, posted only marginal production gains (0.38%) and Kangra experienced a decline (-1.44%). These district-level variations in production growth are also highlighted by Sujan (2024) [8], whose analysis for the 2012-2022 period showed high CAGRs for Sirmour (30.24%) and Mandi (15.88%) districts, alongside negative growth for Shimla (-2.74%) and Kangra (-0.15%) districts. These differences likely stem from multiple factors such as orchard age, adoption of improved varieties, climatic suitability and investment in orchard management. Districts like Mandi and Sirmour might be benefiting from newer plantations and improved farming practices, resulting in faster growth. Similar conclusions were also drawn by Kireeti *et al.* (2015) [6] at the state level, where apple production growth in Himachal Pradesh was found to be primarily area-driven with productivity contributing little to overall output expansion. This supports our results, which showed that area expansion has been the major driver of growth in districts such as Shimla, Kullu and Solan. This is further supported by Ankush and Jai (2023) [1], who found through regression analysis that about 72.6 per cent of the variation in apple production was explained by the area under cultivation. The productivity trends are more concerning as it has declined in key district Shimla (-1.27%) and in Kangra (-3.94%). Meanwhile, Mandi (14.68%), Sirmour (29.35%) and Chamba (11.11%) recorded significant improvements. Again, Sujan's (2024) [8] research supports these patterns, noting sharp productivity declines in Shimla (-4.15%) and Kangra (-4.15%) districts, alongside robust growth in Mandi (15.12%) and Sirmour (32.16%) districts. Dev *et al.* (2024) reported overall increased productivity in zone III (Shimla, Kullu, Mandi and Chamba) by 4.78 per cent followed by zone II (Solan, Sirmour and Kangra) with 3.35 per cent and zone IV (Kinnaur and Lahual Spiti) with 0.57 per cent for the period 1973-2018. However, they also observed a decline in productivity during the second phase from 1990-2018 in the state. The improvements in certain districts may be attributed to younger orchards, better planting material and overall enhanced orchard management. The declining productivity in established regions suggests the need for orchard rejuvenation and better climate resilience. These findings are also consistent with Kireeti *et al.* (2015) [6], who reported high instability in Himachal Pradesh's productivity, attributing it to ageing orchards, erratic weather and low adoption of new technology.

Another key aspect is the year-to-year instability in area, production and productivity revealed high volatility in both production and productivity of Shimla and Kullu districts. These findings are consistent with Sujan's (2024) [8] study, which also categorized Shimla district as having high instability in production (CDVI 34.77%) and productivity (CDVI 35.16%) with Kullu district exhibiting moderate instability in both metrics (production CDVI 26.71%; productivity CDVI 27.27%). In contrast, districts like Sirmour and Lahaul and Spiti districts demonstrated exceptional stability with low CV and CDVI, suggesting a more predictable output, possibly due to favourable climatic conditions or effective orchard management. However, it is important to note a contrasting perspective from Sujan (2024) [8], whose analysis indicated high instability for both Sirmour (production CDVI: 38.30%; productivity CDVI: 38.03%) and Lahaul and Spiti (production CDVI: 30.65%; productivity CDVI: 31.22%), suggesting that the level of variability in these districts might be higher than initially perceived. At the broader state level, [1] *et al.* (2015) [6] similarly highlighted that Himachal Pradesh experienced significant fluctuations in production and yield compared to area, reinforcing our finding that productivity instability remained a major constraint despite the expansion of orchard area.

Conclusion

The study revealed that although the area under apple cultivation in Himachal Pradesh has generally increased, its growth has been uneven. Shimla, Kinnaur and Kullu emerged as the leading districts with higher productivity, while Mandi, Sirmour and Kangra showed relatively lower and unstable output. Despite production growth, instability remains a major issue, primarily driven by climatic variability, irregular rainfall, pest attacks and ageing orchards. Cuddy-Della Valle Index indicated that yield fluctuations contribute more to production instability than changes in area, emphasizing the vulnerability of apple farming to environmental stresses. It is essential to rejuvenate old orchards, adopting high-yielding and climate-resilient varieties, improved irrigation and better post-harvest facilities to ensure sustainable and stable apple production.

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